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Abstract

Habitat loss and habitat fragmentation are major factors leading to forest biodiversity decline. This paper discusses landscape planning as strategy to improve connectivity in a landscape with a heterogeneous distribution of ecologically valuable areas across land owners. A tax-fund system is proposed, that following the principle of common but differentiated responsibility, tries to spread the burden of conservation equally across land owners while optimizing the environmental outcome. Design options of such a tax-fund system are discussed along the lines of a simple theoretical model. Financial effects of a tax-fund system are computed for a small model landscape set in Sweden. Two design questions stand out as particularly important. The first is whether the policy is intended to be self-sustained among the land owners or if the budget can be supplemented by general tax money. The second is whether the land owners or the relevant authority select the stands for conservation set-aside.

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1. Introduction

Globally, a major driver of biodiversity loss in general, and in forests in specific, is habitat destruction (Haddad et al. 2015). Habitat destruction can be seen as a combination of two different phenomena – habitat loss and habitat fragmentation (Fahrig 2003). In this paper we suggest that landscape approaches may be a way forward to decrease habitat destruction and to help countries comply with the targets and obligations set out by international agreements. At the international level, the 20 Aichi Biodiversity Targets which form a part of the Convention of Biological Diversity's (CBD) Strategic Plan for Biodiversity 2011-2020 are important milestones (UNEP, 2013). Target 11 states the ambition to, by 2020, conserve at least 17 per cent of terrestrial areas through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures that are integrated into the wider landscapes. Within the EU, the EU habitat directive (Council Directive 92/43/EEC), also called Natura2000, in addition obliges member states to establish a strict protection regime for some of the listed species, including the protection of breeding sites and resting places.

Spatially, Aichi target nr. 11 refers to the landscape scale. "Landscape", per se, is a widely used term which has several distinct connotations. Conceptually, landscape definitions can be categorized into environment-centered approaches (e.g. in Piorr (2003) and human-centered approaches (e.g. as in the European Landscape Convention). Taking a perspective between the two definitions above Sayer et al. (2013) argue that a landscape can be seen as an arena or dynamic system which is governed by ecological, physical and societal rules and relationships. The landscape boundary is defined by the actors' objectives. Thus from this perspective, the landscape relevant to an environmental policy maker may be equivalent to his or her jurisdiction while the landscape relevant, for example, to a single forest estate owner within that jurisdiction may be significantly smaller.

Although landscape planning for conservation may seem a fairly straightforward approach to improve connectivity of ecologically valuable areas, policy design becomes difficult when landowners are unequally affected by restrictions. Few studies address policy analysis in this area and little is known about financial effects of different policy approaches for forest owners (Parkhurst et al. 2002; Parkhurst and Shogren 2007; Bell et al. 2016).

This paper adds to this literature by proposing a tax-fund system, in which forest owners pay a certain tax and the funds generated through the tax are used to compensate forest owners that are required to set-aside land for conservation purposes. We develop a simple theoretical model to help explain the structure of this tax-fund system. To gain first empirical insights on the tax-fund system, we chose Sweden as a case study. A workshop conducted with forest stakeholders in Sweden allows us to derive an understanding of the relative importance of different design aspects of such a tax-fund system in practice. Moreover, in order to shed light on financial effects of different policies in heterogeneous landscapes with unequal distributions of ecological value across forest estates, we present simulation results for a small model landscape set in Sweden. A major question is whether the landowners can achieve an optimal allocation of conservation sites at least costs by means of a self-sustained tax-fund system, or whether additional government funding is necessary to achieve the optimal solution.

2. Model and Methods

Within a forest landscape, stands of high conservation value are unlikely to be equally distributed across forest owners. Implementing a landscape approach for conservation will thus result in unequal burdens among forest owners, with some required to set aside large amounts of forest while others may need to only set aside little or none at all. A tax-fund system follows the principle of common but differentiated responsibility, in the sense that all forest owners are responsible for conservation and are obliged to contribute. At the same time there is differentiation in the share of set aside between landowners, given the unequal distribution of ecologically valuable sites. Building on the common responsibility of all forest owners, the tax-fund system seeks to level out these differences by imposing a tax on non-conserved land. The funds generated through the tax are used to compensate for the opportunity cost of the conserved land. Internationally, there is a nascent interest in this type of tax-fund system in forestry, see e.g. the California lumber tax of which proceeds are, inter alia, used to reduce the costs of wild land fire suppression (Bill number AB1492).

Below, we first present a model that serves as background for the case study set in Sweden. Section 2.2.1 presents the workshop survey method and section 2.2.2 introduces the simulation methods for the financial effects analysis.

2.1 Model

A simple model of a social planner´s problem eq. (1) and a representative forest owner´s problem eq. (3) is developed to help structure the discussion of issues around the proposed tax-fund system. The social planner's choice variable is the amount of land for conservation in the landscape. The forest owner's choice variable is the amount of productive land, as opposed to set aside land for conservation, within the limits of his own estate. Set in the framework of a tax-fund system, the social planner seeks to determine the optimal amount of conservation area by balancing environmental benefits against opportunity costs of conservation. The forest owner maximizes private income by choosing the optimal amount of productive land, while taking into account the incentives generated by the tax-fund system.

The superscript "SP" stands for social planner and "f" for forest owner. In the following, capital letters stand for variables at landscape scale and lower case letters stand for the private forest owner scale.

The landscape consists of L ha of forest land. The land constraint is given by $L = X + Q$, where X are the hectares that are conserved in the entire landscape and Q is the non-conserved forest area. Equivalently, the forest owner's estate consists of $l = x + q$, where x is the area of conserved land and q is the area of non-conserved land that belongs to the forest owner.

The environmental benefit of the conserved land in monetary units is given by the function $\alpha(X, z)$, with $\partial\alpha/\partial X > 0$ and $\partial^2\alpha/\partial X^2 < 0$; and depends on area, X, and certain characteristics relevant for biodiversity, z. The opportunity cost is expressed by $\rho(X, v)$, $\partial\rho/\partial X > 0$ and depending on the stand characteristics $\partial^2\rho/\partial X^2 \geq 0$ or $\partial^2\rho/\partial X^2 \leq 0$; which is the present value of the land for timber production. It is a function of area, X, and certain land characteristics, v.

The social planner's tax income function for the non-conserved land at landscape scale, $\tau(Q, v, z, S)$, with $\partial\tau/\partial Q > 0$ is a function of the non-conserved area, Q, and the biodiversity and land characteristics v and z. The fund can also be alimented by society at large, i.e. through a share of the country's general tax income, S. The conservation reward function which compensates the forest owner, $t(x, v, z)$, with $\partial t/\partial x > 0$ depends on the conserved area x and land characteristics v and z.

Social planner's problem

The social planner's problem in eq. (1) is thus to choose the amount of land to conserve, X, to maximize the environmental benefit of the conserved land subtractive of its cost of conservation subject to the constraint that the tax income is equal to the amount required for compensation and the land constraint. The social planner's first order condition is given in eq. (2), where λ is the Lagrange multiplier and the land constraint has been substituted into the first constraint. It states that marginal benefit and marginal cost of the amount of conserved land should be equal.

$$\varphi^{SP} = max_x[\alpha(X, z) - \rho(X, v)] \quad (1)$$

s.t. $\rho(X, v) = \tau(Q, v, z, S)$ and $L = X + Q$, with $L, X, Q \geq 0$

$$\frac{\partial\alpha}{\partial X} - \frac{\partial\rho}{\partial X} + \lambda\left(\frac{\partial\tau}{\partial X} - \frac{\partial\rho}{\partial X}\right) = 0 \quad (2)$$

Forest owner's problem

The forest owner chooses the amount of productive land, i.e. non-conserved land, to maximize private income. In eq. (3) this is composed of the present value of the production area minus the tax on this land plus the compensation for the conserved land subject to his land constraint . In eq. (4) the land constraint has been substituted into the reward function. The forest owner's first order condition in eq. (5) states that the benefit of a marginal unit of productive land minus the tax on this land should be equal to the foregone benefit of not setting aside this land.

$$\varphi^f = max_q[\rho(q, v) - \tau(q, v, z) + t(x, v, z)] \quad (3)$$

s.t. land restriction $l = x + q$, with $l, x, q \geq 0$

$$\varphi^f = max_q[\rho(q, v) - \tau(q, v, z) + t((l - q), v, z)] \quad (4)$$

$$\frac{\partial\rho}{\partial q} - \frac{\partial\tau}{\partial q} + \frac{\partial t}{\partial q} = 0 \quad (5)$$

Building on this small descriptive model, several aspects of policy design can be discussed.

2.1.1 Reserve location, continuity and sustainability

Both a regulator and the land owners will want to decide on the location of the reserves within the landscape. The forest owners most likely will want to optimize the spatial distribution of the reserves alongside production forests. A regulator, acting on behalf of society and weighting e.g. connectivity aspects more strongly, may arrive at a different optimal spatial allocation of the reserves. In terms of the model, a regulator will take into account the environmental benefit function, $\alpha(X, z)$. Note that, since we disregard possible environmental valuation motives among the forest owners themselves, this function is not a component of the forest owner's problem. We assume that the forest owner primarily takes into account the opportunity cost of creating a forest reserve, $\rho(x, v)$, i.e. the foregone benefits from forest production. The vector of biodiversity characteristics can be a set of indicators, e.g. on dead woody debris or connectivity to other forest reserves. The set of land characteristics relevant to the forest owner, vector v, may rather contain variables such as average yield or expected yearly income after taxes. Some of the land characteristics contained in vectors z and v may be positively correlated or even equal. An example could be dead woody debris which is relevant for biodiversity and average stand age. In this case, a stand that has high biodiversity value often also has high opportunity costs. Reciprocally, there are likely to be stands with low environmental value and low opportunity costs. Ideally, there are also stands with high environmental value but low opportunity cost. From an efficiency perspective, these should be chosen first. Correspondingly, stands with low environmental value and high opportunity cost would be selected last. This reasoning highlights the importance of ecological information about the relationship between the vectors z and v.

2.1.2 Room for new ideas and duration of the policy

In case the landscape planning program is compulsory and the regulator chooses the forest reserve sites, the compensation payment, $t(x, v, z)$, merely needs to be perceived as more or less fair by forest owners. However, if the forest owners are supposed to voluntarily sign up for forest reserves, the payment should have incentive power and leave room for new ideas in conservation. The expected duration of the policy's life may also play a role. In the literature on payments for environmental services, for instance, there is a controversial debate on optimal contract length (Drechsler et al. 2017). Short-term contracts are likely to lead to spatially more dynamic conservation networks, which may be acceptable in agro-biodiversity contexts but is likely to be suboptimal from a forest conservation perspective where the goal is often to conserve rare old-growth forest patches (Juutinen et al. 2008; Schöttker et al. 2016). Here we hypothesize that forest owners are likely to be more willing to cooperate in conservation if the policy is long-sighted and there are long time spans between changes. Different possibilities exist to create such incentives. For example, the Finnish METSO program on forest biodiversity creates incentives through a reversed auction mechanism (Juutinen and Ollikainen, 2010). Payments for environmental services, in particular the subgroup of conservation performance payments purportedly also create strong conservation incentives (Ferraro and Kiss 2002; Hasund 2013).

2.1.3 Administrative cost

A further aspect that needs consideration, but that is not explicitly visible in the model, is the frequency of the payment for reserves that are set up for a defined number of years. Comparing the transaction costs of purchasing versus leasing forest land for conservation purposes and disregarding risk concerns, Juutinen et al. (2008) find that in the long run, the present value of transaction costs is higher in the lease option than for one-time land purchases. However, even if transaction costs are lower in a one-time up-front payment, questions around risk and liability in case of forest destruction due to natural hazards, e.g. through fire or pests, arise (Palmer 2011). If payments are issued sequentially, transaction costs are likely to be higher, but it may be easier to share risk between regulator and forest owner.

2.1.4 Vertical and horizontal equity

An important question is how the funds to compensate forest owners for forest reserves, $\tau(Q, v, z, S)$, will be collected. In a purely self-supported, landscape-scale tax-fund system, the funds from society's general tax income, S, will be zero, implying little vertical equity between forest owners and society at large. Landscape composition becomes relevant because there needs to be a balance between the amount of money required to compensate for the creation of forest reserves and the amount of producing forest stands that aliment the fund through some form of tax.

Horizontal equity implies that the burdens borne by the forest owners in the landscape are perceived to be distributed in a just manner. The number of forest owners in the landscape is likely to have implications for perceptions of equity. If there is a large number of forest owners in the landscape that contribute to the self-supported fund, it may be easier to establish a feeling of horizontal equity, in the sense that many forest owners are contributing small amounts to compensate for the creation of a modest number of forest reserves. In the limit the "landscape" would be defined as the nation and the tax-fund system would then involve all forest owners. However, for a more narrow definition of a landscape, a situation may arise where a self-supported system would impose high burdens on few forest owners in order to generate the funds required to compensate for the creation of the forest reserves. Such a situation could arise in a federal state (e.g. Germany or the United States) where forest/environmental laws could differ between constituent regions, or for a unitary state (such as Sweden or France) if a tax-fund system was implemented in a specific region as a trial measure. In the latter case, forest owners may feel that horizontal equity between forest owners cannot be established and thus the fund should be complimented with government funding. Augmenting the fund with society's general tax income may be argued to be an improvement in terms of vertical equity because, indeed, the entire society derives a benefit of the forest reserves. This would imply following the beneficiary pays principle.

2.1.5 Choice of tax-type

The desire to establish horizontal equity is closely tied to the design of the tax imposed on the forest owner, $\tau(q, v, z)$. Different types of taxes have been proposed in previous research, that apart from area, q, also take into account different characteristics of the land; as captured in vectors z and v. The literature on different forest taxes is reviewed in (Amacher et al., 2009; Gong and Löfgren, 2013; Koskela et al., 2007). Assuming the forest owners follow a Faustmann-style production system, harvest taxes, such as yield and unit taxes, imply a deduction of gross revenues resulting in an incentive for delaying the harvest. This will lengthen the rotation age. Annual lump-sum taxes, such as the site value or site productivity tax have no bearing on the marginal harvest/delay decision and will thus have no effect on rotation age. However, an annual timber tax levied on the stumpage value of growing timber will shorten the private rotation age resulting in the major tax penalty occurring later – at least for less rapidly growing stands typical for Sweden (cf. Englin and Klan, 1990). Which tax design is perceived as most fair or just needs to be clarified empirically.

2.2 Swedish case study

Sweden is an interesting case in point for an empirical investigation of this policy approach because it is a large wood producing country with a forest cover of about 69% (FAO, 2010) that for several reasons is not fulfilling its biodiversity conservation targets (PROP, 2014/15:1). One of the major hazards to biodiversity is the destruction of forests with long continuity and ecologically favorable characteristics such as large amounts of coarse woody debris and/or significant shares of broadleaved trees. Today, the amount of such forests and other core sites are not sufficient to maintain biological diversity. Moreover, legal requirements on forest management plans were abolished in 1994. The decision was taken in expectation that such planning would continue on a voluntary basis and assuming that the need of such planning is considered as common knowledge. However, as of 2010, forest management plans were developed for only 20 % of the productive forest land in Sweden (Skogsstyrelsen, 2010). According to the Swedish Forestry Agency, it is a general dilemma in conservation that landscape connectivity is not considered (Skogsstyrelsen, 2009).

2.2.1 Workshop survey

To gain insights into the relative importance of these different policy design aspects, we designed a survey addressed to the participants of a workshop held in January 2017 at the Swedish Environmental Protection Agency in Stockholm. The participants were all from Sweden but had different backgrounds; the majority had a background in the forest administration (n=7), others were researchers (n=6) or conservation related stakeholders (n=5). Although a lot of effort was put into contacting and inviting forest owners and representatives of forest owner associations, finally only three stakeholders from this group attended the workshop.

The survey addressed a list of policy design characteristics, which was developed around the discussion of the model above. Explicitly, respondents were asked to distribute 100 points between the 7 choices given in Table 1, a standard ranking question {Vaus 2002 #736}. In an additional question they were asked to indicate what an "equal" distribution of economic burdens means to them. The options 'in proportion to forest area' and 'in proportion to the value of the forest estate' refer to property taxes whereas the other two options rather refer to harvest taxes. The terms were intentionally kept simple for the workshop survey. The participants were requested to answer individually and without discussing with others.

Table 1: Workshop questions

Question
You can influence the choice of the location of the protected area.
Networks of protected forest areas are created that are continuous and sustainable.
The forest policy is long-sighted and consistent and thus there are long timespans between changes.
The forest policy provides room for new conservation ideas from forest owners.
The selection of the protected areas is taken as efficiently as possible to keep the administrative costs for the forest owners low.
The economic burden of creating protected areas in the forest is borne by the Swedish taxpayers in general as far as possible and not by the forest owners.
The economic burden of creating protected areas in the forest – to the extent it is borne by the forest owners – is distributed equally.

Additional question on horizontal equity
With "equal" distribution of the economic burden of creating protected areas in the forest I mean..
in proportion to forest area
in proportion to total income from the forest
in proportion to the felled area
in proportion to the value of the forest estate

2.2.2 Simulation of financial effects

To illustrate the financial effects of a tax-fund system for individual forest owners, we have constructed a stylized, simplified forest landscape with 6 estates with 6 stands each. Although unrealistically small, we argue that, with some caution, the general conclusions from such a simple example can be scaled up to actual forest landscapes.

The management of the stands was planned according to present value maximization using Plan33, a computer program for economic forest management (Ekvall 2014). The timing of final harvest and the number, type (e.g. size of felled trees in relation to those retained), timing and intensity of the thinnings were based on the Faustmann model for defining opportunity cost measures. It is assumed that the stands are tended according to normal forest practice. The applied silvicultural system can be defined as even-aged timber management including regeneration measures, intermediate cuttings and a final clear-cut. The notion of normal forest practice, can be defined as adopting accepted silvicultural measures and complying with the

Swedish Forest Act to achieve production and environmental objectives stated by governmental authorities.

Initially, assume that complying with the Swedish Forest Act implies setting aside 5% of each stand´s area for the benefit of increased biodiversity. This entails costs that forest owners have to accept according to existing legislation.

As mentioned earlier, an artificial forest landscape was created comprising six estates with six equally large (5 ha = 50,000 m^2) Norway Spruce dominated stands. Given that no more than one of the 18 workshop participants found that forest area was a relevant unit of comparison, at least for equality issues, choosing equal sized estates here does not seem to weaken the informative value of the financial effects analysis. The 36 stands were picked randomly from a data file of a municipality forest in the county of Gävleborg in central Sweden, and are thus representative of spruce stands in that region of Sweden. The chosen stands vary in characteristics such as average yield, average age of the trees in the stand, volume of standing trees, etc. Using current (2016) price lists and cost statistics from the local forest owners' association Mellanskog, and using a 3 % interest rate, soil expectation value, present value of the stand, and expected yearly income after tax was calculated for each stand. In Figure 1 below, some basic data for the six estates are presented.

a. Six estates with six stands each

11	14	41	44
12	15	42	45
13	16	43	46
21	24	51	54
22	25	52	55
23	26	53	56
31	34	61	64
32	35	62	65
33	36	63	66

b. Average yield m^3/ha and year

6,3	7,8	8,1	6,3
7,8	8,7	9,0	6,9
4,9	8,1	9,0	5,6
4,9	6,9	6,0	6,9
4,1	6,3	6,3	6,0
7,2	6,0	6,0	6,3
6,9	6,9	6,0	6,0
6,9	7,8	6,6	6,6
6,9	7,8	7,8	8,1

c. Average age of trees, years

11	96	77	4
129	22	70	101
139	40	70	125
38	67	42	13
5	45	11	95
101	107	100	54
71	38	76	72
25	27	26	12
19	41	65	38

d. Standing volume, m^3/ha

10	339	293	1
250	76	368	312
384	149	290	274
100	201	181	17
1	189	7	300
237	296	216	244
252	104	304	197
54	73	64	13
34	182	239	198

e. Present Value of Stand (PVS), 1000 SEK/ha

9	68	65	9
56	27	78	58
64	38	68	49
12	40	28	10
6	31	8	51
47	49	36	39
46	24	48	32
17	21	16	11
15	39	49	41

Figure 1a -e. Stands in the artificial forest landscape. (SEK1000≈USD112, Jan. 2017)

Figure 1a assigns an identification number to each stand in the landscape. For example stand 12 is stand number 2 in estate number 1. Figure 1b shows the average yield for each stand. As can be seen from Figure 3b, the most productive land is situated in estate number one and four (stands 15, 42 and 43), while low productive land can be found in estate two (stand 21) and in the southwest part of estate one (stand 13). Figure 1c shows the average age for standing trees in each stand and Figure 1d indicates the current volume of trees. Figure 1e shows the distribution of the present value of the stands in this artificial forest landscape. When the forest owners' rights to freely use the forest land for production of timber is constrained, the change in present value is an estimation of the opportunity costs that are imposed on the forest owner. The present values in Figure 1e are calculated without concerns about biodiversity beyond the 5% set aside per stand implied by the Swedish Forestry Act. As can be seen from Figure 1e the most valuable stands appear in the "northern" (upper) part of the landscape, specifically in estates one and four.

A first question was which effects a gradual increase of set-aside within each stand would have on the landscape´s total present value.

The subsequent questions focus on the financial effects of different landscape policy options. A general assumption for the simulation exercise is that amendments to the Swedish forest law allow forest owners, in a landscape context, to concentrate biodiversity increasing measures to one or a few larger areas. Moreover, we assume that it is possible to identify sets of stands that will increase biodiversity more, if set-aside, than the old approach did.

The simulation includes five scenarios: A Baseline and then two scenarios termed Area1 and Area2 in which the total conservation area is maintained equal to the Baseline. In two further scenarios, PV1 and PV2, the present value of the landscape is maintained equal to the Baseline. We compare each of the scenarios to the Baseline and assess whether the Kaldor-Hicks efficiency criterion is fulfilled. To do this, in a first step we simply check whether the net change in the present value of stands is positive or negative at the landscape scale. In case it is positive or zero, we further compute whether it is possible to compensate, within a reasonable time frame and under consideration of a 3% interest rate, the losses in present value of those who must set aside more forest land with the gains in expected yearly income after taxes incurred by forest owners who set aside less.

Baseline scenario: This scenario corresponds to the current situation in Sweden. From each stand 5 %, or 0.25 ha of land are set-aside for biodiversity conservation. This amounts to 1.5 ha for each estate, or 9 ha for the whole landscape. The forest owner decides on the location of the set-aside area in each stand. The present value for the entire landscape in this scenario is SEK 6,520,580.

Scenario Area1: In this scenario 9 ha are chosen from the most productive stands because of their biodiversity qualities. The scenario assumes that biodiversity is positively correlated with timber productivity. In Ranius et al. (2005) and in Ekvall et al. (2013) a positive correlation between produced volume of dead wood and timber productivity has been demonstrated.

Scenario Area2: In this scenario 9 ha are primarily chosen from the least productive stands for their low opportunity costs.

Scenario PV1: Stands are selected to maximize the average volume of coarse woody debris (CWD) while maintaining the present value of the landscape equal to the present value of the Baseline scenario[1]. Biodiversity is here defined as the production of coarse woody debris

[1] The solution of the different scenarios is carried out by using traditional nonlinear optimization with a steepest descent approach.

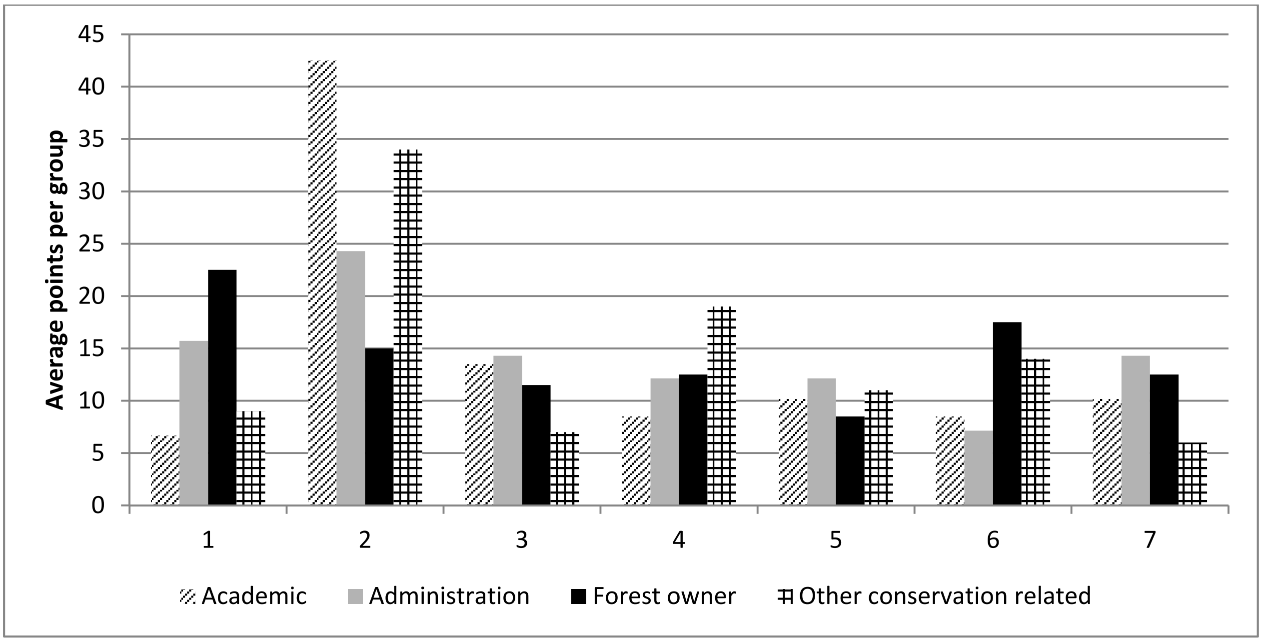
(CWD), which also can be simulated using the Plan33 software. The simulation is based on previous research presented in Ranius et al. (2005).

Scenario PV2: Stands are selected to maximize the total set-aside area in the landscape while maintaining the total present value equal to the present value of the Baseline scenario.

3. Case study results

3.1 Workshop survey

The survey conducted with Swedish forest stakeholders revealed that, on average, the forest owners gave most points to the first answer option, indicating a strong desire to influence the choice of the location of the forest reserve sites (Figure 2). This is in line with previous findings on land owners' preferences for participation in conservation site selection (Pouta et al. 2002; Watzold and Schwerdtner 2005; Blicharska et al. 2016). Interestingly, on average, this was of lesser importance to the members of the administration. This could point to room for negotiation and compromise in a positive sense when it comes to planning reserve sites in a landscape approach. However, overall, achieving the goal of creating networks of protected forest areas that are continuous and sustainable seemed to be most important for the members of the administration. This option was also given most weight by the group of academics and the group of "others". The option addressing vertical equity received second most weight by the forest owners. By contrast, this option received least weight from the administration representatives.



Legend to options: 1) You can influence the choice of the location of the protected area. 2) Networks of protected forest areas are created that are continuous and sustainable. 3) The forest policy is long-sighted and consistent and thus there are long timespans between changes. 4) The forest policy provides room for new conservation ideas from forest owners. 5) The selection of the protected areas is taken as efficiently as possible to keep the administrative costs for the forest owners low. 6) The economic burden of creating protected areas in the forest is borne by the Swedish taxpayers in general as far as possible and not by the forest owners. 7) The economic burden of creating protected areas in the forest – to the extent it is borne by the forest owners – is distributed equally.

Figure 2: Workshop results on relative importance of different policy characteristics (Academic n = 6, Administration n = 7, Forest owner n = 2, Other conservation related n = 5)

Regarding the interpretations of what an "equal" distribution of burdens is (Figure 3), there seems to be little consensus. Although relating burdens to forest area was only seen as a solution to create equality by one person from the group of academics, there is no clear preferred choice among the other three options. Interestingly, the three forest owners that answered this question each responded differently. However, the workshop sample may simply be too small to detect patterns.

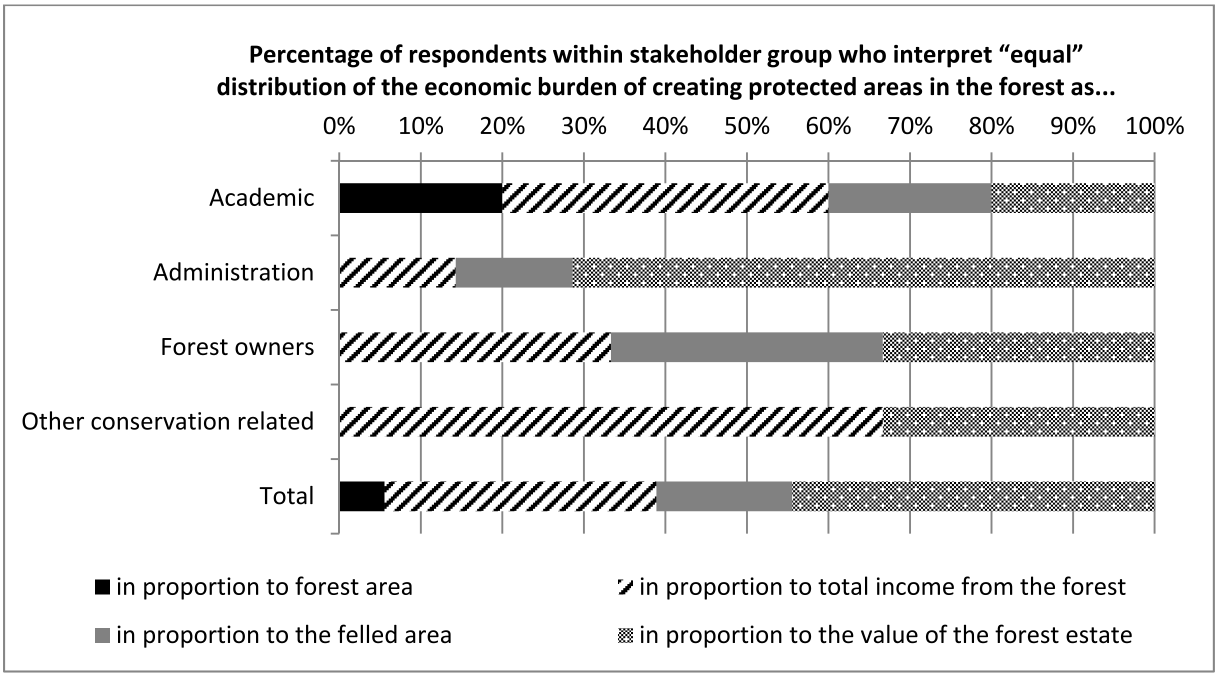


Figure 3: Workshop results on interpretations of “equal” distribution of the economic burden of creating protected areas in the forest (Academic n = 5, Administration n = 7, Forest owners n = 3, Other conservation related n = 3)

3.2 Simulation results

3.2.1 Gradual increase of set-aside

The first question for the simulation concerned the effects of a gradual increase of the percentage of set-aside area in each stand. Figure 4 shows these effects on a typical stand with an average annual growth of 6.0 m3/ha and a stand age of 100 years. The cost of setting aside an increasing percentage of a stand´s area for the benefit of increased biodiversity results in a linear decrease in present value. Although the actual set aside curve looks linear, for other stand data it could also be concave or convex.

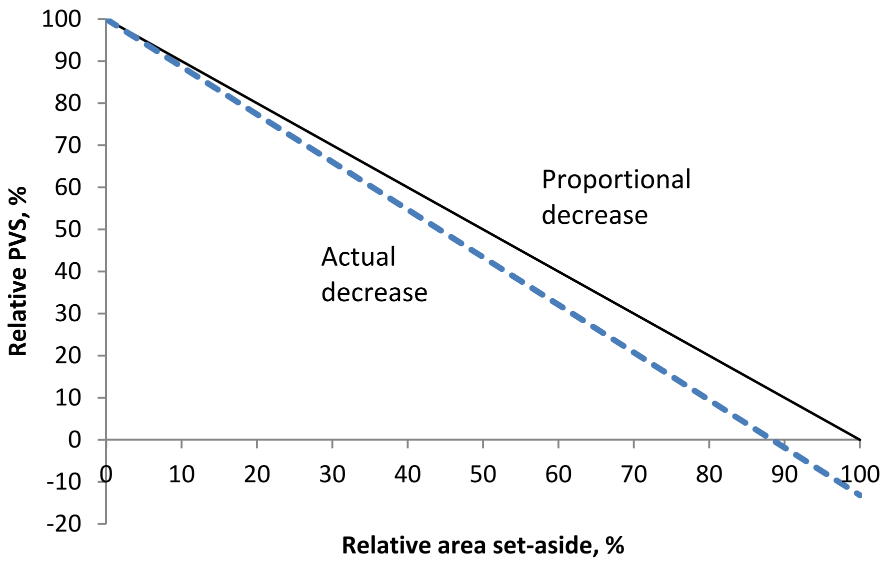


Figure 4. Effects of a gradual increase of set-aside on each stand on landscape's total present value

The shape of the actual decrease curve is unique for each stand and it is influenced by fixed costs hidden in the net revenues of harvesting and silvicultural measures. Fixed cost will not change proportionally to changes in productive stand area. Figure 4 shows that the deviation between a proportional and the actual decrease will increase as the set-aside areas increase. Observe the actual decrease curve crossing the x-axis at 88 percent relative area set-aside. Continued commercial timber production in this stand beyond this breakeven point would be a financial loss, i.e. if you set-aside 88% there is no profitability in timber production on the remaining part of the stand due to fixed costs. When no area is set-aside the total present value of the 36 stands will be about SEK 6,913,900 and when all forest owners are assumed to have complied with existing legislation and set-aside at least 5% of each stand´s area the total PVS will amount to SEK 6,520,580. The difference between these totals is SEK 393,320 or about 5.7 %.

3.2.2 Scenario simulation

The financial effects on the six estates of scenarios Area1 and Area2 in comparison to the Baseline are presented in Table 2. The delta sign denotes a difference between the respective scenarios vis-à-vis the Baseline scenario. A negative number implies a loss vis-à-vis the Baseline scenario.

Table 2: Financial consequences for the three scenarios denoted Baseline, Area1 and Area2.

	Baseline			Area1			Area2		
Estate	SA, ha	EYIAT per year	PVS	SA, ha	ΔEYIAT per year	ΔPVS	SA, ha	ΔEYIAT per year	ΔPVS
1	1.5	39327	1310895	0	2372	79072	0	2372	79072
2	1.5	27734	924459	0	1673	55762	9	-1105	-36831
3	1.5	24115	803817	0	1455	48485	0	1455	48485
4	1.5	49124	1637474	9	-20082	-669411	0	2963	98771
5	1.5	25829	860950	0	1558	51932	0	1558	51932
6	1.5	29490	982984	0	1779	59293	0	1779	59293
Landscape	9	195617	6520580	9	-11246	-374868	9	9022	300721

SA= Set aside; PVS = Present Value of Stands; EYIAT = Expected Yearly Income After Tax; ΔEYIAT = Change in EYIAT relative to Baseline; ΔPVS = Change in PVS relative to Baseline (all monetary values in SEK)

In scenario Area1 nine hectares only situated in estate 4 have been used for biodiversity increasing purposes. Since these stands are very valuable for timber production, the financial loss for the forest owner will be considerable. The expected yearly income after taxes, ΔEYIAT, has decreased with 20,082 SEK/year which means a capital loss of SEK 669,411. On estates 1, 2, 3, 5 and 6, no biodiversity increasing measures are imposed, so both expected yearly income after taxes (EYIAT) and the forest capital (PVS) increase. The consequences for the entire forestry in the landscape will be a loss of income totaling 11,246 SEK/year, which corresponds to a total capital loss of SEK 374,868. Clearly, the loss in yearly income after taxes incurred by owner 4 cannot be compensated by the other owners' gains in yearly income after taxes.

In scenario Area2 nine hectares on estate 2 have been used for biodiversity increasing purposes. Since these stands are not so valuable for timber production, the financial loss for the forest owner will be moderate. The expected yearly income after taxes, ΔEIYAT, has decreased with 1,105 SEK/year, which corresponds to a capital loss of SEK 36,831. On estates 1, 3, 4, 5 and 6, no biodiversity increasing measures are imposed, so both expected yearly income after taxes (EIYAT) and the forest capital (PVS) increase. The consequences for the entire landscape will be a gain of income totaling 9,022 SEK/year, which means a total capital increase of SEK 300,721. The amount available for compensation totals SEK 10,123 per year. Without considering interest, the time needed for full compensation will be 3.6 years (36831/10123) and taking into account an interest rate of 3% the corresponding time increases to 3.9 years. Scenario Area2 thus fulfills the Kaldor-Hicks efficiency criterion when ecological benefits are disregarded.

However, not only the forest owners´ income and wealth are affected when implementing the different scenarios. The production of commercial timber, expressed as average yield, and the average volume of dead wood (Coarse Woody Debris) are affected as well. The volume of CWD in forest stands is considered, by many ecologists, a valuable substrate promoting biodiversity (Ranius et al. 2005).

Table 3. Landscape-scale consequences in terms of finance and production by scenario

(1) Scena-rio	(2) SA, ha	(3) # of parcels	(4) AY, m^3/ha & yr	(5) EYIAT, per year	(6) PVS	(7) CWD, m^3			
Baseline	9	36	6,48	195617	6520580	1608			
	ΔSA		ΔAY	ΔEYIAT	ΔPVS	ΔCWD	(8) ∑ΔEYIAT for all ΔEYIAT >0, SEK/ year	(9) Losses (PVS)	(10) Annuity (payback time is 10 years)
Area1	0	1	-0,11	-11246	-374868	237	8836	-669411	78475
Area2	0	1	0,12	9022	300721	-444	10127	-36831	4318
PV1	3	3	-0,04	0	0	**462**	2899	-96622	11327
PV2	**28**	6	-0,88	0	0	-57	2899	-96622	11327

SA= Set Aside; AY= Average Yield; EYIAT = Expected Yearly Income After Tax; ΔEYIAT = Change in EYIAT relative to Baseline; PVS = Present Value of Stands; ΔPVS = Change in PVS relative to Baseline (all monetary values in SEK); CWD= Coarse Woody Debris

Similar to Table 2, Table 3 compares the four scenarios to the Baseline and adds several additional aspects. The third column indicates the number of parcels, i.e. individual or lumped but non-aligning stands, on which biodiversity promoting measures are carried out. In column 4, average yield (AY, m^3/ha and year), indicates the average growth per hectare and year of trees of commercial value. For instance, when valuable or large areas are set-aside, then the average annual yield per hectare (AY) value is diminishing. Column 7 informs on the average volume of CWD. It is calculated according to functional relationships developed in Ekvall et al. (2013) who also show that the volume of CWD is positively correlated with average yield. Productive land produces more CWD.

In scenario PV1 the volume of CWD is maximized while forcing the financial value of timber production to remain at the same level as in the Baseline scenario. Compared to the Baseline scenario, this results in an increase of the volume of CWD by 462 m3 (29%) and the set-aside area by 3 hectares (33%). In Scenario PV2 the set-aside area is maximized while again maintaining the financial value of timber production equal to its value in the Baseline scenario. The outcome of this scenario is an increase of the set-aside area by 28 hectares (411%) and a decrease of the volume of CWD by 57 m3 (-4%). The downside is that the average timber production decreases by 0.88 (-14%) m3/ha and year. In terms of connectivity the Baseline scenario contains 36 dispersed parcels. Scenarios PV1 form only three parcels and PV2 form six parcels while in scenarios Area1 and Area2 there is only one parcel consisting of aligning stands.

In all scenarios it is assumed that each stand, not affected by a biodiversity promoting measure, can be tended for maximum commercial timber production, which increases the yearly income for many forest owners. Summing all these increased incomes for all stands in the landscape constitutes the yearly pay potential, which is noted in column (8) of Table 3. Ideally the yearly pay potential might then be used to compensate forest owners suffering from capital losses due to biodiversity increasing measures. These losses are noted in Column (9). Finally, in column 10 an annuity with a payback time of 10 years is computed, assuming a 3% interest rate. It corresponds to the total loss of capital for all forest owners in the landscape. If this value is smaller or equal to the pay potential in column (8), it is possible to meet the Kaldor-Hicks efficiency criterion within 10 years. As has already been established above, it is not possible to meet this criterion for scenario Area1 while it is possible for Area2. Moreover, the data reveal that it is not possible to achieve full compensation within 10 years for scenarios PV1 and PV2.

These relationships are illustrated in Figure 5. The lines indicate the annuity that is necessary to compensate for a certain loss (PVS) within a certain timespan. For each of the scenarios the loss that needs to be compensated and the landowners' aggregated positive ΔEYIAT, i.e. the annual pay potential within that scenario is depicted. As can be seen only the point for scenario Area2 is well below the 10year line, indicating that the loss can be compensated within 10 years. Note that for scenarios PV1 and PV2 the financial value of timber production within the entire landscape remains equal to the Baseline scenario. As can be seen from Fig. 5, it would take approximately 100years to achieve the full compensation, and thus to meet the Kaldor-Hicks efficiency criterion.

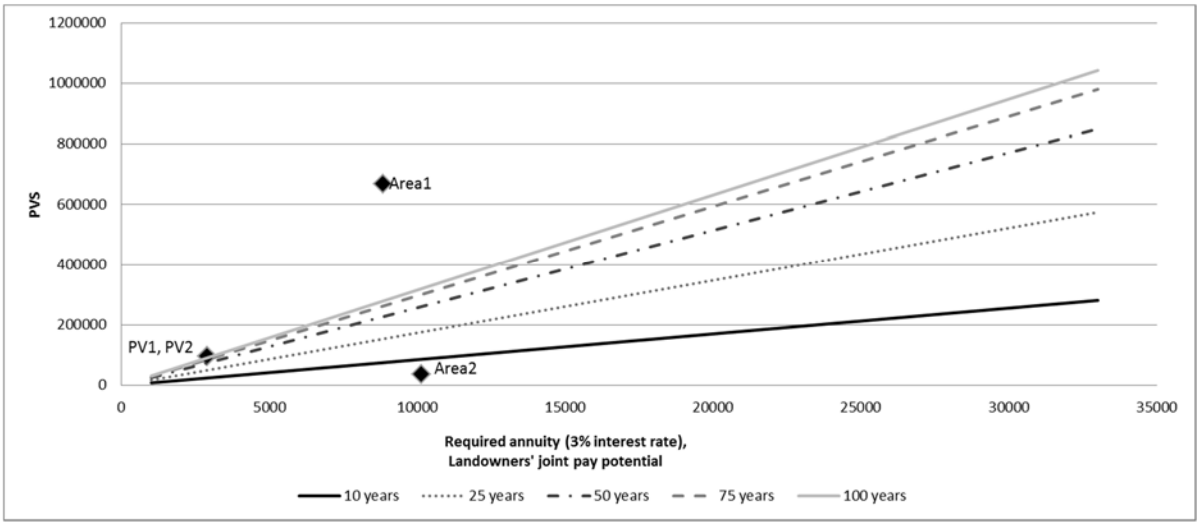


Figure 5: Required annuity and PVS

If forest owners and policy makers could choose among these scenarios, we assume that forest owners would opt for Area2 because they can set-aside the least productive stands and compensation of losses is achievable within a reasonable timeframe. The forest owners´ second best option would supposedly be scenario PV2, in which they can choose stands that maximizes the set-aside area in the landscape. Policy makers interested in optimizing biodiversity values may rather prefer PV1, where ecologists assist forest owners in finding stands that increase the volume of CWD in the landscape or scenario Area1.

3.2.3 Tax-fund system

The financial analysis above helped deduct the contributions that forest owners without constraints on timber production could pay to aliment a fund. The fund would then be used to compensate the forest owners with higher economic burdens. The computations were done with Plan33 which requires empirical data on more than 50 variables from each stand and around 200 additional variables related to regeneration, growth, harvesting, finance and economics (Ekvall, 2001). Although there are similar programs such as the "Stand Method" produced and published by the Swedish Land Survey Authority (National Land Survey of Sweden, 1988), these tools may be overly complicated for use in practice. An interesting question is thus whether a heuristic model, in the sense of a rule of thumb, with fewer variables could be used as second best option and what this would entail in terms of loss of precision. Four readily available field variables are tested for their ability to predict the present value of the model landscapes' stands; average yield (AY, m^3/ha and year), average age of trees (Age, years), average diameter (Diam, cm) and volume of standing trees (Vol, m^3/ha). These variables were individually regressed against the stands' present values as computed by Plan33. Finally in a fifth model average yield and volume were jointly used as predictors. Table 4 presents the OLS results. The results from Table 4 indicate that indeed volume (model 4) as well as average yield and volume (model 5) can serve as reasonably good predictors of the detailed Plan33 results.

Table 4: The ability of selected stand data to predict the present value of a stand

Variable	(1)	(2)	(3)	(4)	(5)
AY	6734.15**				4025.12***
	(2537.1)				(474.83)
Age		392.267***			
		(48.262)			
Diam			1575.37***		
			(112.27)		
Vol				149.379***	142.294***
				(7.88)	(4.57)
constant	-13037.3	10346.2***	1962.87	6163.76***	-20038.5***
	(17545.0)	(3315.6)	(2507.7)	(1681.7)	(3235.9)
R-squared	0.1716	0.6602	0.8527	0.9135	0.9728
Adj. R-squared	0.1473	0.6502	0.8484	0.9110	0.9711

***p<0.01, **p<0.05, *p<0.1

4. Discussion and conclusion

Within the European Union, conservation strategies aimed at improving environmental connectivity, such as Natura2000 or the more recent Green Infrastructure Strategy, are often developed at the broad international level. However, we argue that success of these strategies to a large extent hinges on the implementation of policies at the national level, or perhaps ideally the landscape scale. This paper proposes a tax-fund system as conservation policy for heterogeneous landscapes. Heterogeneity here refers to circumstances when areas of high conservation value are unequally distributed across landowners. The results of our theoretical discussion and the outcomes of the simulation of financial effects show that there is no perfect solution for a tax-fund system, but that the policy needs to be tailored to the specific circumstances. Although the simulation with Plan33 requires a lot of detailed data, the paper finds that proxy variables can be used as simple substitutes. This means that there should be good opportunities for a forest authority to base a tax-fund system on readily available forest characteristics without a large loss of efficiency. However, special attention should be given to the questions (i) whether the policy is intended to be self-sustained among the landscape´s land owners or if the budget can be supplemented by general tax money and (ii) whether the landowners themselves select the conservation sites or if this selection is done by the relevant authority.

At first sight, landowners may always prefer a policy that is supplemented with external money. Indeed with additional external resources to compensate for losses, the set of options will become larger and it may also become easier to find a solution for the juxtaposition of set-aside and productive land. In the financial effects analysis only one out of four scenarios could function as self-sustained policy while the others required supplementary funds. However, landowners may appreciate a self-sustained solution if the policy is part of a voluntary environmental agreement (VEA) by the forest sector. In other contexts VEAs have been established when members of the conceding sector hoped to avert some more restrictive policy or could expect substantial public recognition (Arora and Cason, 1996). In the Swedish case, landowners are legally entitled to compensation. At the same time, the Swedish Forestry Act today does not allow for an effective enforcement even of the minimum legal requirements and possibilities to prosecute landowners for violations are highly limited in practice (Forsberg, 2012). For the Swedish case, this lack of pressure weakens prospects for a landscape-scale VEA.

The second question, whether the landowners or the relevant authority select the conservation sites, as could be seen from the simulation of the Swedish model landscape, can have major impacts on the environmental effectiveness of the program. In existing conservation schemes, the question on site selection has been answered differently. According to the Natura2000 regulations, the member states together with the Commission are obliged to select the areas that are to be included subject to ecological criteria. Thus in Sweden, biotopes of national importance are selected by ecologists on behalf of the government. In voluntary schemes such as for forest biodiversity conservation in Switzerland, forest owners decide whether or not they wish to enroll their land and the cantonal authority offers a compensation price based on given criteria (KAWA, 2016). The Finnish METSO scheme uses a two-step approach in the form of a reversed auction, where forest owners first place conservation bids for their land and the authorities then select stands into the program based on environmental and financial criteria.

However, it remains an interesting question for future empirical research how forest owners evaluate tradeoffs between a self-funded system and full freedom to choose conservation sites versus a government funded program with limited or no participation in site selection.

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